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[Title of the Invention]      Active matrix liquid crystal display device

[Summary]

[Object] An active matrix liquid crystal display device is provided, in which a high-quality display is realized while achieving a sufficient luminance and suppressing an image defect.

[Structure] A black matrix 108 is formed on a TFT substrate side but is not formed on a portion opposing a scanning line 104, so that no electric capacity is formed between the black matrix and the scanning line 104 formed of a metal or semiconductor through an insulating layer. As a result, a problem concerning the image defect caused due to such an electric capacity can be solved. In addition, the black matrix 108 is formed on the TFT substrate side as mentioned above and hence, there arises no problem about an alignment accuracy upon combining substrates. An opening ratio with respect to a pixel electrode 105 can be also increased, making it possible to enhance a luminance of a pixel. Consequently, a high-luminance and high-quality display can be realized.

[Scope of Claim]

[Claim 1] An active matrix liquid crystal display device characterized by comprising: a matrix wiring including a plurality of scanning lines and a plurality of signal lines; a pixel electrode arranged in each intersection of the matrix wiring; a switching device substrate having the pixel electrode and a transistor switching device connected to the matrix wiring; an opposing substrate having an opposing electrode facing the pixel electrode; and a liquid crystal composition nipped between the switching device substrate and the opposing substrate,

the device being equipped with a light-shielding film formed on the switching device substrate so as to cover a gap between the pixel electrodes without substantially covering the scanning lines.

[Detailed Description of the Invention]

[0001]

[Field of the Industrial Application] The present invention relates to an active matrix liquid crystal display device using a switching device composed of a thin film transistor (TFT).

[0002]

[Prior Art] Liquid crystal display devices are being widely used as display devices for a television, a graphic display, etc. Among those, in particular, the active matrix liquid crystal display device enables a high-speed response and suits a display with a large number of pixels. Such devices are expected to realize a high image quality of a display screen, a large screen, a color screen, and the like and are under research and development. Some of the devices have already been put into practical use.

[0003] The active matrix liquid crystal display device has a scanning line and a

signal line arranged perpendicularly to each other on a transparent insulating substrate. Further, in each intersection of the scanning line and the signal line, a switching device and a pixel electrode are disposed.

[0004] The switching device enables drive control of pixels in a distributed manner. Therefore, the pixels can be driven at a high speed and also, increases of the number of pixels and of a screen size can be attained.

[0005] In general, used as the switching device is the thin film transistor (hereinafter, abbreviated to TFT: Thin Film Transistor) having abruptly switchable ON/OFF characteristics fit for its applications.

[0006] The TFT is categorized as an insulated gate field effect transistor, in which a gate is connected to the scanning line, a drain is connected to the signal line, and a source is connected to the pixel electrode, for instance.

[0007] A scanning pulse is applied to the gate, which induces a conductive state between the drain and the source of the TFT including the gate concerned. Thus, a signal voltage is applied to the pixel electrode from the signal line through the source and the drain. If no scanning pulse is applied to the gate, the source and the drain of the TFT including the gate concerned show a high resistance therebetween. Accordingly, no signal voltage is applied to the pixel electrode connected to the source through the drain and a potential of the pixel electrode is retained. In the TFT, such a switching operation is performed.

[0008] The above TFT is generally formed of amorphous silicon (a-Si) or polycrystalline silicon (poly-Si).

[0009] The TFT formed of the amorphous silicon (a-Si) has a feature that it can be formed over a large area of a glass substrate and thus, is suitable for a large-size liquid

crystal display device such as a wall-hung television or an OA display. On the other hand, the TFT formed of the polycrystalline silicon (poly-Si) has a mobility of a carrier as high as 10 to 200 [cm/Vs]. Thus, even if an outer size of the TFT is reduced, driving of the liquid crystal is not affected thereby. In addition, a peripheral drive circuit thereof can be integrally formed on the same substrate by using conventional manufacturing processes. Accordingly, such a TFT is suitable for the liquid crystal display device used for a viewfinder of a camera or a projection television requiring a size reduction and a high definition.

[0010] Fig. 8 is a plan view showing a display pixel region of a conventional liquid crystal display device having a TFT substrate formed of the polycrystalline silicon. Fig. 9 is a sectional view taken along the line A-B of Fig. 8.

[0011] The display pixel region of the liquid crystal display device includes a TFT 801, signal lines 803, scanning lines 804, a pixel electrode 805, and a storage capacitor 806.

[0012] The TFT 801 has a main part composed of an active layer 811 formed of the polycrystalline silicon, a gate insulating film 812, and a gate 813 formed of the polycrystalline silicon with a low resistance.

[0013] The active layer 811 has both sides of a portion facing the gate 813, which are doped with phosphorous (P) as an n-type dopant, to thereby attain a low resistance. A source 814 and a drain 815 are formed therein. The drain 815 is connected to the signal line 803 via an interlayer connection electrode portion of a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, which penetrates an interlayer insulating film 802 through a contact hole. On the other hand, the source 814 is connected to the pixel electrode 805 as a transparent electrode formed of ITO

via an interlayer connection electrode 822 of a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, which penetrates the interlayer insulating film 802 through a contact hole. Also, the gate 813 and the scanning line 804 are integrally formed of the polycrystalline silicon with the low resistance.

[0014] Further, an end 821 of the active layer 811 is arranged opposite to a storage capacitor line 807 through an end 831 of the gate insulating film 812. The storage capacitor line 807 is formed by patterning a polycrystalline silicon film of the low resistance, which constitutes the same layer as that for the gate 813. The end 821 of the active layer 811, the end 831 of the gate insulating film 812, and the storage capacitor line 807 as mentioned above constitute the storage capacitor 806.

[0015] Incidentally, the above TFTs, in particular, the TFTs having the active layer formed of the amorphous silicon (a-Si) cause a photocurrent to be remarkably generated, as is apparent from the fact that the amorphous silicon is used for a solar cell. The photocurrent is also generated in the TFT formed of the polycrystalline silicon. If the TFT is irradiated with light from the outside, the photocurrent generated may cause an erroneous operation of the TFT. Therefore, it is necessary to form a light-shielding film for shielding the light applied to the TFT from the outside in order to keep such a photocurrent from being generated.

[0016] Fig. 10 is a perspective view showing, in a partially omitted form, the above-mentioned TFT substrate 800 and an opposing substrate 900, which are formed face to face. Fig. 11 is a sectional view showing the opposing substrate 900.

[0017] On the opposing substrate 900, a black matrix 908, a color filter 903, and an opposing electrode 905 as the transparent electrode formed of ITO are formed.

[0018] On a glass-made insulating substrate 901, the black matrix 908 is formed,

which is obtained through photo-etching of a thin film formed by depositing metal such as chromium (Cr) into a film by sputtering or the like. The color filter 903 is formed thereon by using a staining method, a pigment dispersion method, a printing method, or the like. Further, formed on the color filter are a transparent electrode layer made of ITO as the opposing electrode 905 and an orientation film 907 whose surface is subjected to a rubbing process for liquid crystal orientation, the film serving to keep the liquid crystal from being directly exposed thereto as well.

[0019] The black matrix 908 is the light-shielding film obtained through the photo-etching of the thin film formed of metal such as chromium (Cr), which is deposited on the opposing substrate 900 as mentioned above. As shown in Fig. 10, the light-shielding film is formed to such a pattern that the film has an opening only at a portion facing each pixel electrode but covers the other portions, i.e., portions facing each gap between the pixel electrodes for shielding the light.

[0020] When the opposing substrate 900 is combined with the TFT substrate 800 face to face after alignment with a high accuracy, the opening of the black matrix 908 is directly above the pixel electrode 805 on the TFT substrate 800 such that the light passes through the portion corresponding to the pixel electrode 805 but does not pass through the other portions corresponding to the gap between the signal line 803 or the scanning line 804 and the pixel electrode 805, and the TFT.

[0021] By using the black matrix 908, the light to be applied to the TFT 801 from the outside is shielded to avoid the erroneous operation of the TFT caused by the photocurrent. At the same time, a decrease in contrast ratio is prevented, which results from a leak of the light passing through the gap between the matrix wiring composed of the signal line 803, the scanning line 804, etc., and the pixel electrode

805.

[0022]

[Problems to be solved by the Invention] However, the above black matrix is generally formed on the opposing substrate side, so that if the TFT substrate and the opposing substrate are misaligned, the light leaks through the gap between wirings including the signal line 803, the scanning line 804, etc., and the pixel electrode 805. This causes the display defect. For example, in the case of using a white-mode liquid crystal display device, there arises a problem in that the pixels in the portion corresponding to the light leak look bright as if to be illuminated all the time, which causes the decreased contrast ratio and a non-uniform display as the image defect.

[0023] Accordingly, upon combining the TFT substrate and the opposing substrate, the alignment should be performed with a high accuracy. However, such alignment with the high accuracy is hard to perform. To cite an example of the alignment accuracy, in general, the liquid crystal display device having a size of about 5 inches in diagonal admits misalignment of about  $\pm 2 \mu\text{m}$  and that having a size of about 10 inches admits the misalignment of  $\pm 3 \mu\text{m}$ . It is difficult from the viewpoint of manufacturing techniques to much further increase the alignment accuracy. Furthermore, as for a pixel size of the liquid crystal display device, there is an increasing tendency of miniaturization more and more to meet demands for the high definition. Therefore, the alignment will be supposedly more difficult to perform in the future.

[0024] Generally adopted as a countermeasure against such misalignments is a method of forming the black matrix so as to overlap with the pixel electrode to such a degree as to correspond to approximately a dimension regarding the alignment

accuracy. With such an arrangement, the misalignment upon combining the TFT substrate and the opposing substrate is allowed while counting on the dimension of such an overlap portion. However, the fact that the black matrix includes the overlap portion with the pixel electrode means that an opening area of the black matrix with respect to the pixel electrode decreases accordingly, which leads to a problem in that the pixel reduces its luminance more as an opening ratio thereof decreases.

[0025] Further, the TFT substrate and the opposing substrate differ in thermal history in their respective manufacturing processes and thus, differ in how much a thermal expansion or an expansion and contraction proceeds. Accordingly, there arises a problem in that a pattern pitch itself changes in the manufacturing process, thereby making it more difficult to perform the accurate alignment as well. To solve this problem, the black matrix should include the larger overlap portion. However, as a result thereof, another problem arises in that the opening area of the black matrix with respect to the pixel electrode more reduces, and the luminance of the pixel becomes lower.

[0026] As mentioned above, when the black matrix is formed on the opposing substrate side, there arises the problem about the misalignment upon combining the TFT substrate and the opposing substrate.

[0027] To cope with the problem, it is conceivable that the black matrix is incorporated onto the TFT substrate side. This is because the alignment of the pixel electrode and the black matrix on the same substrate can be achieved with a high accuracy that approximates 1 $\mu$ m.

[0028] However, when the black matrix is incorporated onto the TFT substrate as mentioned above, there causes such problems that a structure of the TFT substrate



becomes complex and further, the manufacturing process is complicated, resulting in an increase in production cost due to a reduced yield or the like.

[0029] In addition, the black matrix is generally formed using a metal thin film formed of chromium (Cr) etc. Thus, such a metal thin film is formed close to the matrix wiring including the signal line and the like or an upper or lower layer of the TFT while covering the same, which causes a problem about formation of electric capacity.

[0030] In particular, the scanning pulse passing through the scanning line is largely affected by such an electric capacity. There arises a problem in that the foregoing electric capacity leads to a delay or waveform rounding of the scanning pulse. That is, an operation delay or error of the TFT occurs, which results in the occurrence of the image defect on an image on the liquid crystal display device in the end.

[0031] The present invention has been made with a view to solving the above-mentioned problems, and accordingly it is an object of the present invention to provide a liquid crystal display device capable of realizing a display with a high quality and a sufficient luminance, in which a black matrix covering a gap between a matrix wiring including a signal line or the like and a the pixel electrode, and a TFT with a high accuracy is formed to thereby solve a problem about a decrease in luminance of a display pixel, eliminate a problem about an occurrence of a display defect of the liquid crystal display device, which results from an operation delay or error of the TFT, and suppress the occurrence of the display defect.

[Means for solving the Problems]

[0032] In order to solve the above-mentioned problems, an active matrix liquid crystal display device according to the present invention is characterized by including:

a matrix wiring including a plurality of scanning lines and a plurality of signal lines; a pixel electrode arranged in each intersection of the matrix wiring; a switching device substrate having the pixel electrode and a transistor switching device connected to the matrix wiring; an opposing substrate having an opposing electrode facing the pixel electrode; and a liquid crystal composition nipped between the switching device substrate and the opposing substrate, the device being equipped with a light-shielding film formed on the switching device substrate so as to cover a gap between the pixel electrodes without substantially covering the scanning lines.

[0033] Note that, the light-shielding film that is so-called the black matrix may be formed in an upper layer or a lower layer, or an intermediate layer of a layer structure of the switching device substrate. At this time, however, the black matrix needs to be formed such that a light entering the TFT from the outside is shielded so as not to expose the TFT to such a light and also, that no light leaks from the gap between the pixel electrodes.

[0034] Further, the black matrix may be formed to cover neither the scanning line nor the signal line as needed.

[0035] Also, the black matrix, according to its arrangement position and shape, may be arranged to partially cover the scanning line or overlap the scanning line to such a degree that an electric capacity formed between the matrix and the scanning line is substantially negligible. This is because, for example, in the case where the black matrix is formed in a layer distant from the layer where the TFT and the scanning line are formed to some degree, it is conceivable that the light obliquely entering the switching device substrate may reach the TFT or such a light may leak from an opening. Thus, to avoid those situations, a certain area of overlap portion is

necessary.

[0036]

[Operation] The black matrix as the light-shielding film is formed on the TFT substrate (so-called switching device substrate) side having the matrix wiring including the scanning line and the signal line, a TFT device, the pixel electrode, and the like. Consequently, there arises no problem of light leak due to misalignment of the substrates unlike the case where the black matrix is formed on the opposing substrate side and the gap between the matrix wiring and the pixel electrode, and the TFT can be covered by the black matrix with the high accuracy. Therefore, the overlap portion between the black matrix and the pixel electrode can be considerably minimized and the problem concerning the decrease in luminance of the display pixel resulting from the reduced opening area of the black matrix with respect to the pixel electrode can be solved.

[0037] Also, the above black matrix is formed to cover not the scanning line but the gap between the electrodes and hence, no electric capacity is formed with the scanning line made of a metal, a semiconductor, etc., through an insulating layer. As a result, the occurrence of the operation error or delay of the TFT owing to the waveform rounding or delay of the scanning pulse caused by the electric capacity is suppressed to eliminate the image defect of the liquid crystal display device. Thus, the high-quality image display can be realized with a sufficient luminance while suppressing the occurrence of the image defect.

[0038]

[Embodiment] Hereinafter, referring to the drawings, a detailed description will be given of an embodiment of an active matrix liquid crystal display device according to

the present invention.

[0039] (Embodiment 1) Fig. 1 is a plan view showing a display pixel portion of an active matrix liquid crystal display device according to Embodiment 1 of the present invention. Fig. 2 is a sectional view taken along the line A-B of Fig. 1. Fig. 3 is a plan view of the active matrix liquid crystal display device according to Embodiment 1 as viewed from a quartz-made transparent insulating substrate side.

[0040] The active matrix liquid crystal display device according to Embodiment 1 includes a TFT substrate having a black matrix formed in a lower layer of a TFT, an opposing substrate facing the TFT substrate, and a liquid crystal composition nipped between both the substrates.

[0041] Here, a description will be made focusing on the TFT substrate having the black matrix disposed thereon as a main part of this embodiment.

[0042] A TFT 101, signal lines 103, scanning lines 104, a pixel electrode 105, a storage capacitor 106, and a black matrix 108 constitute a main part of a display pixel portion of the TFT substrate of this embodiment.

[0043] As a layer structure thereof, the black matrix 108 as a light-shielding film including a metal film made of titanium (Ti), tungsten (W), etc., or a silicide film thereof, a silicon oxide ( $\text{SiO}_2$ ) film 109, an active layer 111 made of polycrystalline silicon (p-Si) of the TFT, a gate insulating film 112, a gate 113 made of the polycrystalline silicon (poly-Si) with a low resistance, the scanning line 104, a storage capacitor line 107, an interlayer insulating film 102, the pixel electrode 105 as a transparent electrode made of ITO or the like, the signal line 103 having a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, an interlayer connection electrode 122, and a protective film 123 made of  $\text{SiN}_x$  are formed in the

order from the bottom on the quartz-made transparent insulating substrate 100.

[0044] The TFT 101 as a switching device has a main part constituted of the above-described active layer 111 including a source 114 and a drain 115, the gate insulating film 112, and the gate 113.

[0045] The active layer 111 has both sides of a portion facing the gate 113, which are doped with phosphorous (P) as an n-type dopant, to thereby attain a low resistance. The source 114 and the drain 115 are formed therein. The drain 115 is connected to the signal line 103 of a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, which penetrates the interlayer insulating film 102 through a contact hole. On the other hand, the source 114 is connected to the pixel electrode 105 as a transparent electrode formed of ITO via the interlayer connection electrode 122 of a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, which penetrates the interlayer insulating film 102 through a contact hole. Also, the gate 113 and the scanning line 104 are integrally formed of the polycrystalline silicon with the low resistance.

[0014] Further, an end 121 of the active layer 111 is arranged opposite to the storage capacitor line 107 through an end 131 of the gate insulating film 112. The storage capacitor line 107 is formed by patterning a polycrystalline silicon film with the low resistance, which constitutes the same layer as that for the gate 113. The end 121 of the active layer 111, the end 131 of the gate insulating film 112, and the storage capacitor line 107 constitute the storage capacitor 106 as a MOS capacitor.

[0047] The black matrix 108 corresponding to a shaded area of Fig. 1 is a light-shielding film having a thickness of approximately 200 nm, which is arranged to cover a gap between a matrix wiring having the scanning line 104 and the signal line

103 intersecting each other, and the pixel electrode 105, and the TFT 101 but not to cover the pixel electrode 105, the scanning line 104, the signal line 103, and the storage capacitor line 107. As shown in Fig. 3, however, in order to more surely avoid the leak of the light, a certain overlap portion is involved insofar as there gives no influence that may induce a reduction in contrast ratio or the like.

[0048] As in the conventional cases, the black matrix arranged on the opposing substrate side needs to have the overlap portion with the pixel electrode of about 2 to 3  $\mu\text{m}$  in order to cope with misalignment thereof. In the case of a pitch between the pixels of 60  $\mu\text{m}$ , an opening ratio of an opening is 30%. However, in the black matrix 108 according to the present invention, it is possible to reduce a size of the foregoing overlap portion to 1  $\mu\text{m}$  or less. Therefore, the opening ratio of the opening can be increased up to 40% and hence, the reduction in pixel luminance or contrast ratio is suppressed to realize the high-quality image display with a sufficient luminance, in which the occurrence of the display defect is suppressed.

[0040] Also, the black matrix 108 is arranged so as not to cover the scanning line 104, so that no electric capacity is formed with the scanning line 104 through the silicon oxide ( $\text{SiO}_2$ ) film 109 as an insulating layer, or the like. As a result, the occurrence of the operation error or delay of the TFT 101 owing to the waveform rounding or delay of the scanning pulse caused by the electric capacity is suppressed to eliminate the image defect of the liquid crystal display device. Thus, the high-quality image display can be realized with a sufficient luminance while suppressing the occurrence of the image defect.

[0050] Also, the black matrix 108 according to this embodiment is formed so as not to cover the signal line 103, so that no electric capacity is formed between the black

matrix 108 and the signal line 103. As a result, a problem such as a variation of a signal voltage resulting from the electric capacity is eliminated as well.

[0051] Further, the metal-made black matrix 108, as apparent from Figs. 2 and 3, underlies the gap between the signal line 103 and the pixel electrode 105, which accordingly functions as an electric shield to suppress crosstalk between the signal line 103 and the pixel electrode 105. Therefore, a potential variation of the pixel electrode 105 caused by the crosstalk with the signal line 103 is suppressed. When actually measuring such a potential variation of the pixel electrode 105 caused by the above crosstalk, it is confirmed that a potential variation ratio of the liquid crystal display device according to the conventional techniques is 1.0%, whereas that of the liquid crystal display device according to this embodiment can be reduced down to 0.7% at the time of applying no voltage to the black matrix 108 and 0.3% at the time of applying thereto a voltage almost equal to the potential of the opposing electrode.

[0052] A manufacturing method for the active matrix liquid crystal display device of this embodiment as mentioned above will be explained in the step order in brief.

[0053] On the quartz-made transparent insulating substrate 100, a metal film made of titanium (Ti), tungsten (W), etc., or a silicide film thereof is formed by sputtering or the like with a thickness of about 200 nm and patterned through photoetching etc., forming the black matrix 108.

[0054] Next, the silicon oxide ( $\text{SiO}_2$ ) film 109 having a thickness of about 800 nm is formed over the entire surface of the substrate by normal pressure CVD, plasma CVD, or the like.

[0055] Next, the polycrystalline silicon (poly-Si) film is formed by low-pressure CVD, followed by solid phase growth at 600°C for 24 hours. After that, patterning is

performed to obtain the active layer 111. The end 121 of the active layer 111 on the source 114 side is formed opposite to the storage capacitor line 107 so as to serve as an electrode of the storage capacitor 106. Then, the gate insulating film 112 is formed on the active layer 111 surface through thermal oxidation.

[0056] Subsequently, the polycrystalline silicon (poly-Si) film is formed by the low-pressure CVD and patterned into the gate 113, the scanning line 104, and the storage capacitor line 107. Phosphorous (P) as an n-type dopant is injected into the active layer through ion implantation to form the source 114 and the drain 115.

[0057] Next, the silicon oxide ( $\text{SiO}_2$ ) is deposited into a film as the interlayer insulating film 102 by the low-pressure CVD and furthermore, an ITO film is formed by sputtering as the pixel electrode 105.

[0058] After that, contact holes are formed in the interlayer insulating film 102, on which the signal line 103 having the two-layer structure of the aluminum (Al) layer and the chromium (Cr) layer and the interlayer connection electrode 122 are formed.

[0059] The protective film 123 made of  $\text{SiN}_x$  is formed by plasma CVD so as to fully cover the top thereof.

[0060] As mentioned above, to the active matrix liquid crystal display device according to this embodiment, almost all the conventional manufacturing processes subsequent to the process for forming the black matrix 108 directly above the quartz-made transparent insulating substrate 108 can be applied. Thus, it is substantially free of the complicated operation for adding any special manufacturing process and the increase in production cost and is superior also in view of the manufacturing method.

[0061] (Embodiment 2) Fig. 4 is a plan view showing a pixel portion of an active



matrix liquid crystal display device according to Embodiment 2 of the present invention. Fig. 5 is a sectional view taken along the line A-B of Fig. 4. Note that for easily understanding the gist of the present invention, in the figures, a display pixel portion of the active matrix liquid crystal display device in the form of the storage capacitor being omitted is shown.

[0062] A layer structure of the display pixel portion of the TFT substrate according to this embodiment includes, as shown in Fig. 5, an active layer 211 of the TFT, which is made of the polycrystalline silicon (poly-Si), a gate insulating film 212, a gate 213 made of the polycrystalline silicon (poly-Si) with a low resistance, a scanning line 204, an interlayer insulating film 202, a pixel electrode 205 as a transparent electrode made of ITO or the like, a signal line 203 having a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, an interlayer connection electrode 222, a protective film 223 made of  $\text{SiN}_x$ , and a black matrix 208 as a light-shielding film including a metal film made of titanium (Ti), tungsten (W), etc., or a silicide film thereof, which are formed in the order from the bottom on a quartz-made transparent insulating substrate 200. The black matrix 208 has a thickness of about 200 nm. In addition, the thickness of the protective film 223 is set to 300 nm.

[0063] As shown in Fig. 4, the black matrix formed on an uppermost layer of the TFT substrate in this way takes such a planar shape as to cover the gap between the pixel electrodes 205 and the TFT 201 but not to cover the pixel electrode 205 and the scanning line 204. However, in order to more surely avoid the leak of the light, the overlap portion is somewhat involved insofar as there gives no influence that may induce a reduction in contrast ratio or the like. The size of the overlap portion is 1  $\mu\text{m}$  or less and an opening ratio of an opening with respect to the pixel electrode 205

can be increased up to 40% to thereby suppress the reduction in pixel luminance and contrast ratio. Thus, the high-quality image display can be realized with a sufficient luminance while suppressing the occurrence of the image defect.

[0064] Further, when such a potential variation of the pixel electrode 205 caused by the crosstalk between the signal line 203 and the pixel electrode 205 is measured, it is confirmed that a potential variation ratio of the liquid crystal display device according to the conventional techniques is 1.0% and that of the liquid crystal display device according to Embodiment 1 is 0.7%, whereas the potential variation ratio of the pixel electrode 205 is 0.5% even if no voltage is applied to the black matrix 208 according to Embodiment 2. This is because the black matrix 208 according to Embodiment 2 is arranged closer to the pixel electrode 205 and the signal line 203 than that of Embodiment 1 and hence, an electric-shielding effect can be enhanced.

[0065] (Embodiment 3) Fig. 6 is a plan view showing a pixel portion of an active matrix liquid crystal display device according to Embodiment 3 of the present invention. Fig. 7 is a sectional view taken along the line A-B of Fig. 6. Note that for easily understanding the gist of the present invention, in the figures, an active matrix liquid crystal display device in the form of the storage capacitor being omitted is shown.

[0066] In Embodiment 3, a black matrix 308 is arranged overlying the matrix wiring composed of scanning lines 304 and signal lines 303 and a TFT 301 and underlying a pixel electrode 305. The matrix is formed in such a planar shape as to cover the gap between the pixel electrodes 305 and the TFT 301 but not to cover the pixel electrode 305 and the scanning line 304. However, in order to more surely avoid the leak of the light, the overlap portion is somewhat involved insofar as there gives no influence

that may induce a reduction in contrast ratio or the like. The size of the overlap portion is 1  $\mu\text{m}$  or less and an opening ratio of an opening with respect to the pixel electrode 305 can be increased up to 40% to thereby suppress the reduction in pixel luminance and contrast ratio. Thus, the high-quality image display can be realized with a sufficient luminance while suppressing the occurrence of the image defect.

[0067] A layer structure of a display pixel portion of the TFT substrate according to this embodiment includes, as shown in Fig. 7, an active layer 311 of the TFT, which is made of the polycrystalline silicon (poly-Si), a gate insulating film 312, a gate 313 made of the polycrystalline silicon (poly-Si) with a low resistance, a scanning line 304, an interlayer insulating film 302, a signal line 303 having a two-layer structure including an aluminum (Al) layer and a chromium (Cr) layer, an interlayer insulating film 324 made of  $\text{SiN}_x$ , a black matrix 308 as a light-shielding film including a metal film made of titanium (Ti), tungsten (W), etc., or a silicide film thereof, a protective film 323 made of  $\text{SiN}_x$ , and a pixel electrode 305 as a transparent electrode made of ITO or the like, the electrode being formed integrally with an interlayer connection electrode 322, which are formed in the stated order from the bottom on a quartz-made transparent insulating substrate 300.

[0068] The thickness of the black matrix 308 is set to about 200 nm, and the thicknesses of the protective film 323 and the interlayer insulating film 324 are set to about 200 nm, respectively.

[0069] With the above arrangement of the black matrix 308, in this embodiment, the potential variation ratio of the pixel electrode 305 owing to the crosstalk with the pixel electrode 305 can be reduced to 0.4%, which is much smaller than that of Embodiment 2. This is because the black matrix 208 according to Embodiment 2 is arranged still

closer to the pixel electrode 205 and the signal line 203 than that of Embodiment 1 and hence, an electric-shielding effect can be further enhanced.

[0070]

[Effects of the Invention] As described in detail so far, the active matrix liquid crystal display device according to the present invention has the black matrix covering the gap between the matrix wiring composed of the scanning line and the signal line, and the pixel electrode, and the TFT with a high accuracy, whereby the problem of the decrease in luminance of the display pixel is solved as well as the problem of the occurrence of the display defect of the liquid crystal display device resulting from the operation error or delay of the TFT is solved. Consequently, the high-quality image display can be realized while maintaining the sufficient luminance and also, suppressing the occurrence of the display defect.

[Brief Description of the Drawings]

[Fig. 1] A plan view showing a display pixel portion of an active matrix liquid crystal display device according to Embodiment 1 of the present invention.

[Fig. 2] A sectional view taken along the line A-B of the display pixel portion of the active matrix liquid crystal display device according to Embodiment 1 of the present invention.

[Fig. 3] A plan view of the active matrix liquid crystal display device according to Embodiment 1 of the present invention as viewed from a quartz-made transparent insulating substrate side.

[Fig. 4] A plan view showing a pixel portion of an active matrix liquid crystal display device according to Embodiment 2 of the present invention.

[Fig. 5] A sectional view taken along the line A-B of the pixel portion of the active

matrix liquid crystal display device according to Embodiment 2 of the present invention.

[Fig. 6] A plan view showing a pixel portion of an active matrix liquid crystal display device according to Embodiment 3 of the present invention.

[Fig. 7] A sectional view taken along the line A-B of the pixel portion of the active matrix liquid crystal display device according to Embodiment 3 of the present invention.

[Fig. 8] A plan view showing a display pixel region of a conventional active matrix liquid crystal display device.

[Fig. 9] A sectional view taken along the line A-B of the display pixel region of the conventional active matrix liquid crystal display device.

[Fig. 10] A partially omitted perspective view showing a TFT substrate 800 and an opposing substrate 900 formed opposite thereto.

[Fig. 11] A sectional view showing the opposing substrate 900.

[Description of Symbols]

100 ... quartz-made transparent insulating substrate

101 ... TFT

102 ... interlayer insulating film

103 ... signal line

104 ... scanning line

105 ... pixel electrode

106 ... storage capacitor

107 ... storage capacitor line

108 ... black matrix

- 109 ... silicon oxide ( $\text{SiO}_2$ ) film
- 111 ... active layer
- 112 ... gate insulating film
- 113 ... gate
- 114 ... source
- 115 ... drain
- 121 ... end of the active layer on the source side
- 122 ... interlayer connection electrode
- 123 ... protective film
- 131 ... end of the gate insulating film